Plastic-Insulated Winding Wires

Norddeutsche Seekabelwerke GmbH & Co. KG
P.O. Box 14 64
D-26944 Nordenham
Germany

Tel: +49 4731 82 0
Fax: +49 4731 82 1520

www.nsw.com

November 2001

Plastic-Insulated Winding Wires

1. General Information
2. Design, Dimensions and Weights
3. Delivery Lengths and Packaging
4. Physical Properties
5. Testing

The following information is intended to describe the product NSW delivers to its customers. It is not a guarantee of properties.

1. General Information

1.1 Description

1.2 History

1.1. Description

Submersible motors are used as wet motors in fluids, and thus the wires used in submersible motor windings require high-quality insulation that is completely impervious to liquids. NSW winding wires are specially designed to meet the requirements of this application. They have proven their durability and reliability over many decades and ensure trouble-free operation and long motor life. NSW winding wires consist of a solid or multi-stranded bare copper conductor insulated by means of a plastic sheath made of one of the following materials:

PVC
PE2
HT4

Electric motor manufacturers have found that PVC-insulated winding wires can be used for voltages up to 1,000 V and at temperatures up to 60 °C. PE2-insulated winding wires are generally used in submersible motors operating under higher voltages and at temperatures of up to approximately 85 °C. The increased resistance to heat is achieved by cross-linking the polyethylene. NSW HT4-insulated winding wires are the most effective solution for operating temperatures of up to approximately 115 °C. To ensure long-term stability with this material NSW recommends a minimum sheath wall thickness of 0.6 mm. The thickness of the sheath wall is a function of the operating voltage. For voltages of 3 kV and more NSW recommends the use of a semiconducting layer between the copper conductor and the insulating sheath.

The surface of winding wires which are insulated with PE2 have a thin sheathing of polyamide (PA) for surface protection.

1.2. History

NSW (Norddeutsche Seekabelwerke GmbH & Co. KG) has been developing and manufacturing underwater cables and wires since the company was founded in 1899. Initially, NSW produced wires for transoceanic telegraph and telephone cables. On the basis of this experience the company began producing plastic-insulated winding wires for submersible motors (wet-stator motors) in 1946. Decades of work and research ensure the high quality of this product.

NSW manufactures and tests its products in accordance with its own in-house quality management system which has been certified by Lloyd's Register Quality Assurance in accordance with ISO 9001.

The PVC blend used in NSW winding wires was developed specially for this purpose, and over the course of many years the materials chosen for NSW´s PE2 and HT4 insulation have proved their worth and reliability.

A polyamide sheath provides good mechanical protection for NSW´s PE2-insulated winding wires.

NSW´s state-of-the-art laboratories continually test the suitability of new insulating materials for use in its winding wires. NSW has broad experience in the manufacture of special wires, and for many decades its partners have trusted the high quality and performance which they have - justifiably - come to expect.

2. Design, Dimensions and Weights

2.1. Design

Solid conductor: Cross section in mm^2: 0.283 to 16.6 — Diameter in mm: 0.6 to 4.6

Stranded conductor: Cross section in mm^2: From approx. 3.5

Insulation wall thickness : Depending on dimensions and operating voltage from 0.3 mm

PA sheathing: From 0.1 mm to 0.2 mm wall thickness, depending on external diameter of the insulated conductor

Special dimensions available on request

Tolerance levels:

The permissible tolerance levels for the external diameter of NSW plastic-insulated winding wires are, depending on the thickness of the walls, as follows:

External diameter in mm	Tolerance of external diameter for wall thickness w in mm				Maximum eccentricity
	$w \leq 1.0$	$1.0 < w \leq 1.5$	$1.5 < w \leq 2.5$	$2.5 < w \leq 3.5$	
Up to 2.5	± 0.05	-	-	-	Half the permissible tolerance of the external diameter
Above 2.5 up to 7.0	± 0.10	± 0.10	± 0.15	± 0.20	
Above 7.0 up to 12.0	± 0.15	± 0.15	± 0.20	± 0.20	
Above 12.0 up to 15.0	± 0.20	± 0.20	± 0.20	± 0.20	

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.1 Solid conductor with PVC insulation

Cu cross section mm²	Cu diameter mm	PVC diameter mm	PVC wall thickness mm	Cu weight kg/km	Total weight kg/km
0.636	0.90	1.60	0.35	5.66	7.72
0.785	1.00	1.70	0.35	6.99	9.22
0.950	1.10	1.80	0.35	8.46	10.85
1.13	1.20	1.90	0.35	10.2	12.7
1.33	1.30	2.10	0.40	11.8	15.0
1.54	1.40	2.20	0.40	13.7	17.1
1.77	1.50	2.30	0.40	15.7	19.3
2.01	1.60	2.30	0.35	17.9	21.1
2.01	1.60	2.40	0.40	17.9	21.7
2.27	1.70	2.50	0.40	20.2	24.2
2.54	1.80	2.60	0.40	22.6	26.8
2.84	1.90	2.70	0.40	25.2	29.6
3.14	2.00	2.90	0.45	28.0	33.2
3.46	2.10	3.10	0.50	30.8	37.0
3.80	2.20	3.20	0.50	33.8	40.2
4.15	2.30	3.30	0.50	37.0	43.6
4.52	2.40	3.60	0.60	40.3	48.7
4.91	2.50	3.50	0.50	43.7	50.8
4.91	2.50	3.70	0.60	43.7	52.5
5.31	2.60	3.60	0.50	47.3	54.6
5.31	2.60	3.80	0.60	47.3	56.3
5.73	2.70	3.70	0.50	51.0	58.5
6.16	2.80	4.00	0.60	54.8	64.4
6.61	2.90	4.10	0.60	58.8	68.7
7.07	3.00	4.20	0.60	62.9	73.1
8.04	3.20	4.40	0.60	71.6	82.3
8.04	3.40	4.70	0.65	80.8	93.2
10.2	3.60	5.20	0.80	90.6	107

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.2 Stranded conductor with PVC insulation

Cu cross section mm²	Design	Cu diameter mm	PVC diameter mm	PVC wall thickness mm	Cu weight kg/km	Total weight kg/km
7.95	19 x 0.73	3.65	4.90	0.625	71.5	84.1
9.08	19 x 0.78	3.90	5.20	0.650	81.7	95.6
10.0	19 x 0.82	4.10	5.40	0.650	90.2	105
12.1	19 x 0.90	4.50	5.90	0.700	109	126
13.2	19 x 0.94	4.70	6.10	0.700	119	136
14.0	19 x 0.97	4.85	6.40	0.775	126	147
14.9	19 x 1.00	5.00	6.60	0.800	134	156
16.1	19 x 1.04	5.20	6.90	0.850	145	169
18.1	19 x 1.10	5.50	7.20	0.850	162	188
20.1	19 x 1.16	5.80	7.40	0.800	180	205
21.2	27 x 1.00	6.15	7.80	0.850	191	218
25.7	27 x 1.10	6.80	8.50	0.850	232	263

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.3 Solid conductor with PE2 insulation and PA sheathing

Cu cross section mm²	Cu diameter mm	PE2 diameter mm	External diameter mm	PE2 wall thickness mm	PA wall thickness mm	Cu weight kg/km	Total weight kg/km
1.54	1.4	2.2	2.4	0.40	0.10	13.7	16.5
1.77	1.5	2.3	2.5	0.40	0.10	15.7	18.7
2.01	1.6	2.4	2.6	0.40	0.10	17.9	21.0
2.27	1.7	2.5	2.7	0.40	0.10	20.2	23.5
2.54	1.8	2.6	2.8	0.40	0.10	22.6	26.1
2.84	1.9	2.7	2.9	0.40	0.10	25.2	28.8
3.14	2.0	2.9	3.1	0.45	0.10	28.0	31.5
3.46	2.1	3.0	3.3	0.45	0.15	30.8	35.7
3.80	2.2	3.1	3.4	0.45	0.15	33.8	38.8
4.15	2.3	3.2	3.5	0.45	0.15	37.0	42.2
4.52	2.4	3.4	3.7	0.50	0.15	40.3	46.2
4.91	2.5	3.5	3.8	0.50	0.15	43.7	49.8
5.31	2.6	3.6	3.9	0.50	0.15	47.3	53.5
5.73	2.7	3.8	4.1	0.55	0.15	51.0	58.0
6.16	2.8	3.9	4.2	0.55	0.15	54.8	62.1
6.61	2.9	4.0	4.3	0.55	0.15	58.8	66.3
7.07	3.0	4.2	4.5	0.60	0.15	62.9	71.2
8.04	3.2	4.4	4.7	0.60	0.15	71.6	80.4
9.08	3.4	4.7	5.0	0.65	0.15	80.8	90.7
10.2	3.6	4.9	5.2	0.65	0.15	90.6	101
11.3	3.8	5.1	5.4	0.65	0.15	101	112
12.6	4.0	5.4	5.7	0.70	0.15	112	124
13.9	4.2	5.7	6.1	0.75	0.20	123	138
16.6	4.6	6.1	6.5	0.75	0.20	148	164

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.4 Stranded conductor with PE2 insulation and PA sheathing

Cu cross section mm²	Design	Cu diameter mm	PE2 diameter mm	PA external diameter mm	PE2 wall thickness mm	PA wall thickness mm	Cu weight kg/km	Total weight kg/km
7.95	19 x 0.73	3.65	4.90	5.30	0.625	0.20	71.5	83.5
9.08	19 x 0.78	3.90	5.20	5.60	0.650	0.20	81.7	94.9
10.0	19 x 0.82	4.10	5.40	5.80	0.650	0.20	90.2	104
12.1	19 x 0.90	4.50	5.90	6.30	0.700	0.20	109	125
13.2	19 x 0.94	4.70	6.10	6.50	0.700	0.20	119	135
14.0	19 x 0.97	4.85	6.40	6.80	0.775	0.20	126	145
16.1	19 x 1.04	5.20	6.90	7.30	0.850	0.20	145	165
18.1	19 x 1.10	5.50	7.20	7.60	0.850	0.20	162	185
21.2	27 x 1.00	6.15	7.80	8.20	0.825	0.20	191	216
25.7	27 x 1.10	6.80	8.50	8.90	0.850	0.20	232	260

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.5 Solid conductor with HT4 insulation

Cu cross section mm^2	Cu diameter mm	HT4 diameter mm	HT4 wall thickness mm	Cu weight kg/km	Total weight kg/km
1.54	1.4	2.4	0.50	13.7	18.8
2.01	1.6	2.8	0.60	17.9	24.9
2.27	1.7	2.9	0.60	20.2	27.6
2.84	1.9	3.1	0.60	25.2	33.2
3.14	2.0	3.2	0.60	28.0	36.3
3.80	2.2	3.4	0.60	33.8	42.8
4.52	2.4	3.6	0.60	40.3	49.9
6.16	2.8	4.0	0.60	54.8	65.7
7.07	3.0	4.5	0.75	62.9	77.9
9.08	3.4	5.0	0.80	80.8	98.8
10.20	3.6	5.2	0.80	90.6	109
11.90	3.9	5.5	0.80	106	126

2.2. Standard dimensions and weights of winding wires for operating voltages of up to 690 V

2.2.6 Stranded conductor with HT4 insulation

Cu cross section mm^2	Design	Cu diameter mm	HT4 diameter mm	HT4 wall thickness mm	Cu weight kg/km	Total weight kg/km
7.95	19 x 0.73	3.65	5.00	0.675	71.5	89.0
13.2	19 x 0.94	4.70	6.10	0.700	119	142
16.1	19 x 1.04	5.20	7.30	1.050	145	184
18.1	19 x 1.10	5.50	7.60	1.050	162	203
21.2	27 x 1.00	6.15	7.80	0.825	191	227
25.2	19 x 1.30	6.50	8.20	0.850	227	266

2.3. Standard dimensions and weights of winding wires for operating voltages of 3 kV

2.3.1 Solid conductor with PE2 insulation and PA sheathing

Cu cross section mm^2	Cu diameter mm	PE2 diameter mm	PA external diameter mm	PE2 wall thickness mm	PA wall thickness mm	Cu weight kg/km	Total weight kg/km
3.80	2.20	5.00	5.30	1.40	0.15	33.8	50.9
4.52	2.40	4.70	5.00	1.15	0.15	40.3	54.4
4.52	2.40	5.20	5.50	1.40	0.15	40.3	58.2
5.31	2.60	5.40	5.70	1.40	0.15	47.3	66.1
5.73	2.70	5.00	5.30	1.15	0.15	51.0	66.2
5.73	2.70	5.50	5.80	1.40	0.15	51.0	70.3
6.16	2.80	5.10	5.40	1.15	0.15	54.8	70.5
7.07	3.00	5.80	6.10	1.40	0.15	62.9	83.6
8.04	3.20	6.20	6.60	1.50	0.20	71.6	96.1
9.08	3.40	5.70	6.00	1.15	0.15	80.8	98.7
10.2	3.60	6.40	6.80	1.40	0.20	90.6	115
10.8	3.70	6.50	6.90	1.40	0.20	95.7	121
11.3	3.80	6.60	7.00	1.40	0.20	101	126
13.2	4.10	6.40	6.80	1.15	0.20	118	139
13.2	4.10	6.90	7.30	1.40	0.20	118	144
13.9	4.20	6.50	6.90	1.15	0.20	123	145
13.9	4.20	7.00	7.40	1.40	0.20	123	151
14.5	4.30	6.60	7.00	1.15	0.20	129	152
15.2	4.40	7.20	7.60	1.40	0.20	135	164
15.9	4.50	7.30	7.70	1.40	0.20	142	170
16.6	4.60	7.40	7.80	1.40	0.20	148	177

2.4. Standard dimensions and weights of winding wires for operating voltages of 6 kV

2.4.1 Solid conductor with semi-conductive layer, PE2 insulation and PA sheathing

Cu cross section mm²	Cu diameter mm	HL diameter mm	PE2 diameter mm	PA diameter mm	Wall thickness HL mm	Wall thickness PE2 mm	Wall thickness PA mm	Cu weight kg/km	Total weight kg/km
3.80	2.20	2.80	7.20	7.60	0.30	2.20	0.20	33.8	72.6
4.52	2.40	2.80	6.20	6.50	0.20	1.70	0.15	40.3	67.0
4.52	2.40	2.80	7.20	7.60	0.20	2.20	0.20	40.3	78.3
5.31	2.60	3.00	6.40	6.70	0.20	1.70	0.15	47.3	75.1
5.31	2.60	2.90	7.30	7.70	0.15	2.20	0.20	47.3	85.7
6.16	2.80	3.10	7.50	7.90	0.15	2.20	0.20	54.8	94.7
7.07	3.00	3.50	7.80	8.30	0.25	2.15	0.25	62.9	107
8.04	3.00	3.60	8.00	8.40	0.20	2.20	0.20	71.6	116
8.04	3.20	3.70	7.10	7.60	0.25	1.70	0.25	71.6	107
8.04	3.20	3.60	8.60	9.10	0.20	2.50	0.25	71.6	125
8.04	3.20	3.60	8.00	8.50	0.20	2.20	0.25	71.6	117
9.08	3.40	4.00	9.00	9.50	0.30	2.50	0.25	80.8	138
10.2	3.60	4.20	8.60	9.00	0.30	2.20	0.20	90.6	140
10.2	3.60	4.00	8.40	8.90	0.20	2.20	0.25	90.6	139
11.3	3.80	4.20	8.80	9.20	0.20	2.30	0.20	101	152
12.6	4.00	4.40	8.80	9.20	0.20	2.20	0.20	112	162
12.6	4.00	4.50	9.00	9.50	0.25	2.25	0.25	112	166
16.6	4.60	5.00	9.20	9.60	0.20	2.10	0.20	148	200

3. Delivery Lengths and Packaging

3.1. Standard delivery lengths

The standard delivery lengths for winding wires with solid conductors are:

When packaged in coils

Internal diameter of coil: 300 mm

Ø of copper conductor in mm:	Delivery lengths in m:
0.40 to 0.65	up to 700
0.70 to 1.00	up to 1150
1.10 to 1.60	up to 600
1.70 to 2.70	up to 500
2.80 to 2.90	up to 400

When packed on reels with cylindrical cores

Ø of copper conductor in mm:	Reel type (size)	Delivery lengths in m:
0.40 to 0.90	350	up to 2000
1.00 to 1.10	350	up to 1800
1.20 to 1.30	350	up to 1500
1.40 to 1.60	350	up to 1000
1.70 to 2.00	500	up to 2000
2.10 to 2.50	500	up to 1500
over 2.50	800	or wooden drums

When packed on reels with conical cores

Ø of winding wire in mm:	Delivery lengths in m:
1.60 to 2.20	up to 3500
2.30	up to 3200
2.40	up to 2900
2.50	up to 2700
2.60	up to 2500
2.70	up to 2300
2.80	up to 2100
2.90	up to 2000
3.00	up to 1900
3.10	up to 1700
3.30	up to 1500

Delivery lengths for winding wires with stranded conductors are agreed upon individually with the customer.

Deliveries can contain a portion of short lengths down to minimum lengths of 400 m for solid conductors and 200 m for stranded conductors.

3.2. Delivery forms and packaging

As a rule, winding wires are delivered on reels.
As a special form of delivery, they can also be supplied as coils.

The packaging used is selected to provide the most suitable protection against damage or impairment.

Examples of packaging:

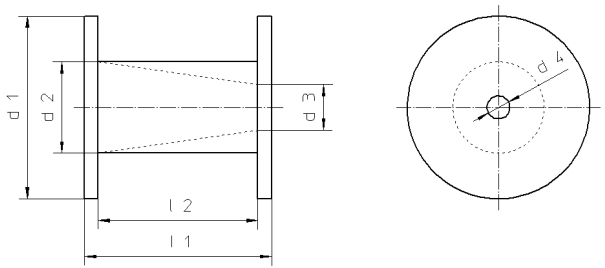
- Wire coils wrapped individually in crepe paper

- Reels protected by a layer of cardboard

- Wooden drums protected with a layer of cardboard or panelled with boards.

For the dimensions of the reels and drums used, please see Section 3.2.1

3.2.1 Reel and drum dimensions



Reel dimensions in mm:

Reel type	d_1	d_2 / d_3	d_4	l_1	l_2	s	Nominal weight in kg
350	355	224	36	200	160	20	Approx. 1.8
500	500	250	30	300	260	20	Approx. 7.0
800	800	400	78	510	440	35	Approx. 24
400 KS	400	260 / 175	80	463	400	38 / 25	Approx. 2.6

Drum dimensions in mm:

Drum type	d_1	d_2	d_4	l_1	l_2	s	Nominal weight in kg
07	710	355	80	520	400	48	Approx. 25
08	800	400	80	520	400	48	Approx. 31
09	900	450	80	690	560	48	Approx. 47
10	1000	500	80	710	560	48	Approx. 71

4. Physical Properties

4.1. Physical properties of plastics used for winding wire insulation

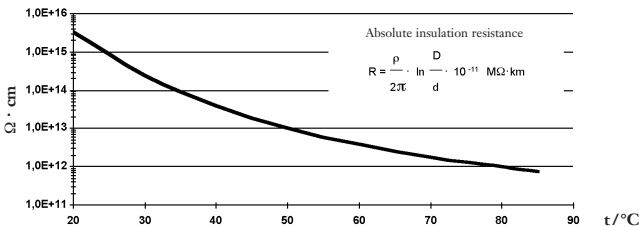
Testing characteristics	Unit	Standards	Typical Data		
			HT4	PE2	PVC
Tensile strength (at (23±5) °C	N/mm²	IEC 60811-1-1	≥ 10	≥ 10	≥ 10
Elongation at break (at (23±5) °C)	%	IEC 60811-1-1	≥ 100	≥ 100	≥ 90
Tensile strength after aging (7 x 24 h, 80 °C)	N/mm²	IEC 60811-1-1 IEC 60811-1-2	≥ 10	≥ 10	≥ 10
Elongation at break after aging (7 x 24 h, 80 °C)	%	IEC 60811-1-1 IEC 60811-1-2	≥ 100	≥ 100	≥ 90
Longitudinal shrinkage Testing temperature Shrinkage	 °C %	IEC 60811-1-3	 115 ≤ 4	 90 ≤ 4	 70 ≤ 4
Hot penetration Testing temperature Penetration depth	 °C %	IEC 60811-3-1	 115 ≤ 5	 90 ≤ 25	 70 ≤ 40
Dielectric constant ϵ_r (at 20 °C, 800 Hz)		DIN 534483 Supplementary sheet 1 DIN 53483-1 DIN 53483-2	2.6	2.3	3...4
Specific insulation resistance (at 20 °C)	Ω · cm	IEC 60093	10^{17}	10^{18}	10^{15}
Dielectric breakdown strength (at 20 °C, 50 Hz)	kV/mm	DIN VDE 0303-21	85	70	60

Recommended storage and processing temperature: Approx. 20 °C

4.2 Electrical properties of plastic-insulated winding wires

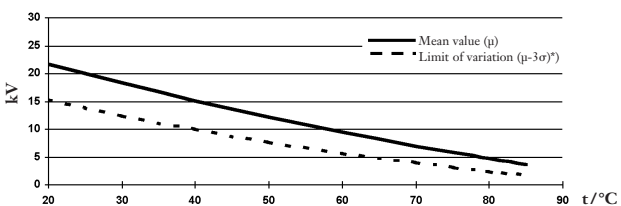
4.2.1 PVC-insulated winding wire

Specific insulation resistance ρ; Ω · cm



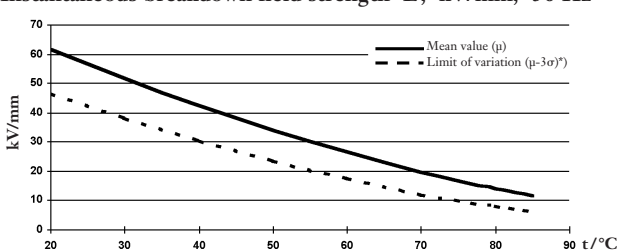
Instantaneous breakdown voltage U; kV, 50 Hz

Voltage increase: 100 V/s
Wire 1.1 / 2.0 mm ø



Instantaneous breakdown field strength E; kV/mm, 50 Hz

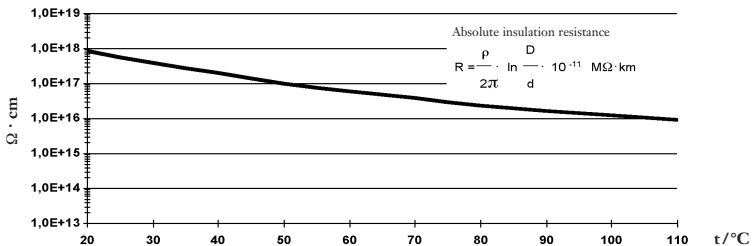
*) Limit of variation (μ-3σ) : 99.7% of all breakdown values are above the given limit



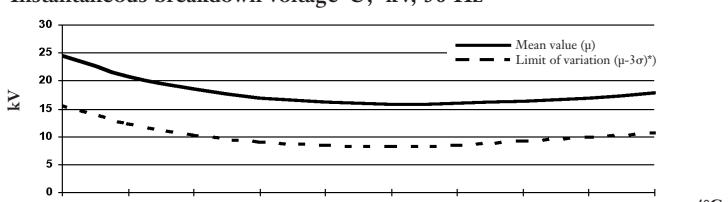
4.2 Electrical properties of plastic-insulated winding wires

4.2.2 PE2-insulated winding wire

Specific insulation resistance ρ; Ω · cm

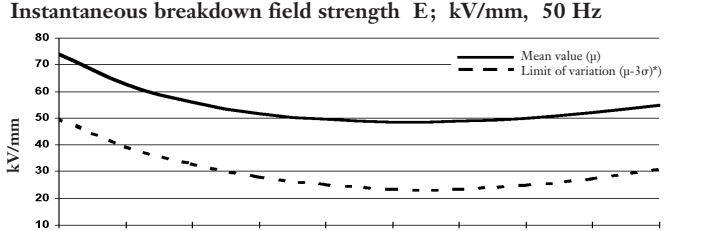


Instantaneous breakdown voltage U; kV, 50 Hz



Voltage increase: 100 V/s
Wire 1.1 / 2.0 mm ø

Instantaneous breakdown field strength E; kV/mm, 50 Hz

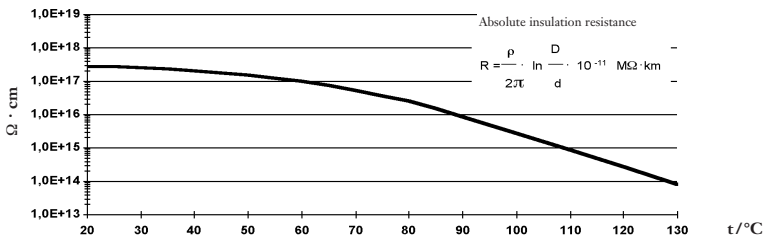


*) Limit of variation (μ-3σ) : 99.7% of all breakdown values are above the given limit

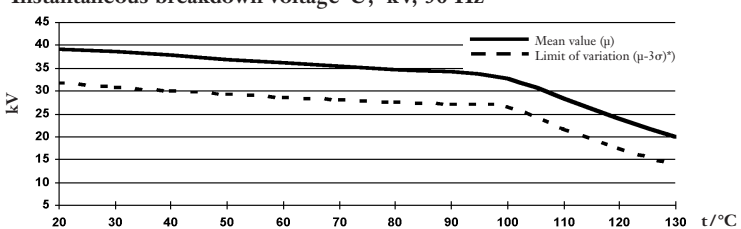
4.2 Electrical properties of plastic-insulated winding wires

4.2.3 HT4-insulated winding wire

Specific insulation resistance ρ; Ω · cm

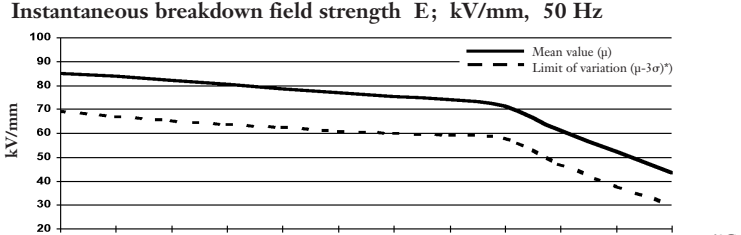


Instantaneous breakdown voltage U; kV, 50 Hz



Voltage increase: 100 V/s
Wire 1.8 / 3.0 mm ø

Instantaneous breakdown field strength E; kV/mm, 50 Hz

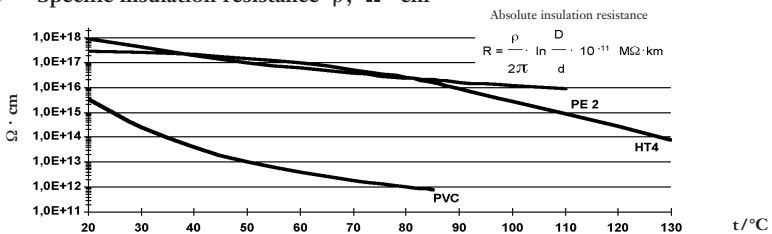


*) Limit of variation (μ-3σ) : 99.7% of all breakdown values are above the given limit

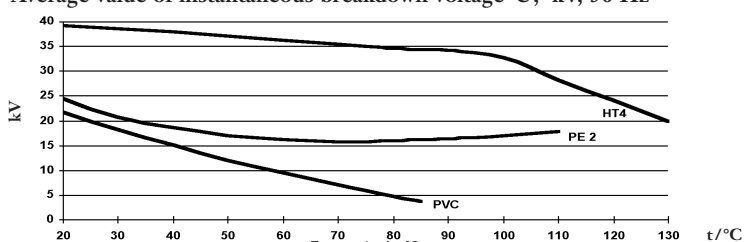
4.2 Electrical properties of plastic-insulated winding wires

4.2.4 Summary of some of the electrical properties of plastic-insulated winding wires

Specific insulation resistance ρ; Ω · cm

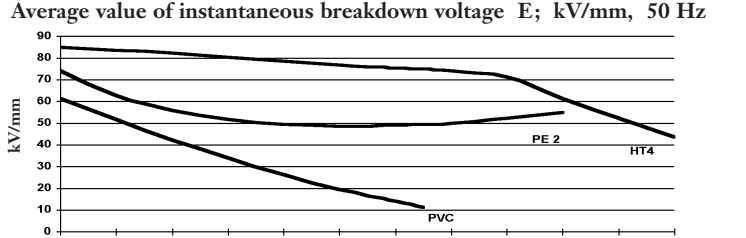


Average value of instantaneous breakdown voltage U; kV, 50 Hz



Voltage increase : 100 V/s
PE2, PVC wire 1.1 / 2.0 mm ø
HT4 wire 1.8 / 3.0 mm ø

Average value of instantaneous breakdown voltage E; kV/mm, 50 Hz



5. Testing

5.1 Final testing

5.1.1 Dimensions and mechanical tests

Routine tests at room temperature

- Diameter, wall thickness, concentricity, surface characteristics
- Tensile strength, elongation at break, shrinkage

5.1.2 Electrical tests

Routine testing in mains water bath

- High-voltage testing

The test is carried out with alternating current (50 Hz) after the winding wire has been in a bath of water at a temperature of approx. 15°C for 24 hours.

Test voltage and test duration for **standard dimensions:**

For operating voltages of up to 1 kV:

U_{test} = 4 kV Test duration = 1 minute

For operating voltages of over 1 kV:

$U_{test} = 2\ U_{op} + 1$ kV Test duration = 10 minutes

Directly after the alternating current test, the insulation resistance of the winding wire is tested using a direct current of at least 500 V.

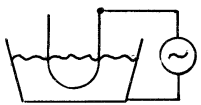
Comments:

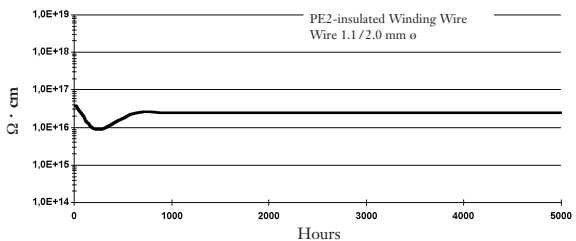
If a customer´s specifications have been agreed upon in a contract, the customer's requirements apply.

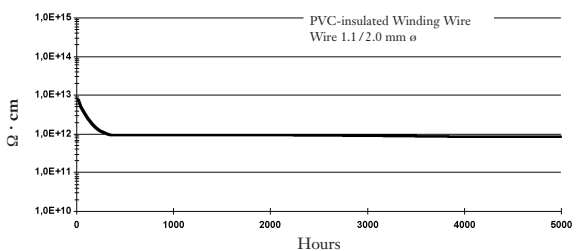
If desired by the customer, a test certificate 3.1 B in accordance with the German industrial standard DIN EN 10204 can be issued certifying that the product has successfully passed the final test.

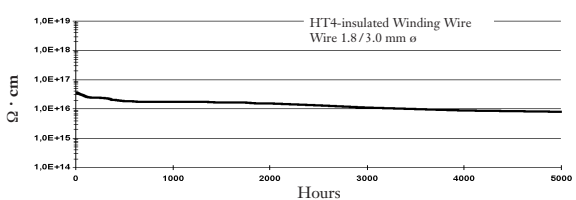
5.2 Extended duration testing

Time-dependent characteristics of the specific insulation resistance under an alternating current load of 600 V in a water bath at a temperature of 80 °C









5.3 Type tests

At regular intervals, samples of wire are taken from the current production batch and subjected to type testing.

During type tests the

Specific insulation resistance
Instantaneous breakdown voltage
Instantaneous breakdown field strength

are tested as a function of the temperature (t).

Testing procedure

Winding wire samples are stored in a tempered testing basin filled with water. Starting at 20 °C, the temperature in the testing basin is increased in steps of 20 °C . The samples remain at each temperature level until the insulation resistance is constant.

The specific insulation resistance of the samples is monitored over the entire duration of the test. In order to determine the immediate disruptive voltage and the immediate disruptive field strength, some of the samples are destruction-tested at the end of each temperature level.